NOVEL 'SOFT' HORN ANTENNA FOR MULTIBAND OPERATION

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This paper presents some preliminary results obtained during an experimental investigation into the feasibility of a novel broad-band and/or multi-band horn antenna [1]. The concept employs passive array or Frequency Selective Surface (FSS) technology to allow colocation of several frequency selective horns (FSH), each designed and optimised for one frequency band of interest. Figure 1 shows an example of a compact pyramidal antenna formed from two FSHs arranged coaxially with a common feed at the apex. At low frequencies, the array forming the outer horn is resonant whilst the array forming the inner horn is almost transparent. Hence the device behaves as a horn with dimensions equal to that of the outer horn. At higher frequencies, the inner horn is resonant whilst the outer one is transparent, so that the device behaves as a horn with dimensions dictated by the inner structure. In this way a horn is produced whose wall positions are dependant on the frequency of operation. For large band spacings, we have two horns, colocated, each of which will ideally perform in the absence of the other, resulting in a high performance dual/multi band integrated horn. The band separation is primarily dictated by the resonant frequencies of the coaxial FSHs and, inevitably, by the coupling between them.

In order to show that a horn antenna may be fabricated from array elements, a prototype conical horn was made by simply folding a sector of an etched surface into a 'soft' cone. Its apex was inserted into the open end of a waveguide whilst the profile of the surface contained a smooth transition from rectangular to circular cross-section. A comparable horn, termed here as solid, was made in the same way from flexible dielectric-backed copper sheet. Figure 2 shows the sector used to make the cone along with a cross-section of the resulting horn. The dimensions annotated are as follows: $\alpha_c = 80^0$, $L_c = 16$cm, $L_T = 19.4$cm, $\alpha_s = 12.8^0$, L=15.6cm and d=4.4cm. A double-square element geometry was used where the inner square's side length l_i=3.1mm and the outer side length l_o=5.2mm. The widths of the inner and outer squares were 0.1mm and 0.7mm respectively. The array elements were arranged on a closely packed square lattice of side D=5.5mm and printed on a 0.05mm thick dielectric substrate (ε_r=3). The surface was glued to a 0.1mm thick acetate former (ε_r=2.33) to provide rigidity. The horn's surface area was 0.025m^2 which accommodated over 840 conducting elements. The electric field of the waveguide was taken parallel to y_h and the sector axis y was in the y_h-z_h plane. As a consequence of using a square-lattice, the array elements are oriented at varying angles to the boresight axis at different positions on the curved surface.

Figure 3 shows the boresight frequency response of the FSH ('soft' horn) compared with that of the solid (copper) horn and open waveguide. It may be seen that near the resonance of the array (around 15 GHz) the gain of the FSH approaches that of the solid horn, indicating that at this frequency the array walls are indeed acting as good reflectors. Away from this frequency the response approaches that of the open

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waveguide, indicating that the walls are becoming inert. Also shown in Figure 3 is the measured plane wave transmission response of a large array at normal incidence. As expected, there exists a null which is broadly coincident with the 'soft' horn's band centre. The matching was improved near the horn design frequency but worsend out of band. This is consistent with the design philosophy of the horn. There is about 2dBi gain decrease which is partly due to the lossy adhesive used and partly due to the array's discontinuity mismatches along the line joining the sector in the horn construction.

Figure 4 shows the copolar and crosspolar patterns of the 'soft' horn at 14.5 GHz. There is a disparity between the E and H planes and the peak crosspolar level is about 20 dB below the boresight level. This is not unreasonable considering the wide variation of local incidence on the elements as well as the array asymmetry resulting from laying a square lattice onto a conical surface. Figure 5 shows the H plane radiation patterns for the FSH, copper horn and open waveguide at 14.5 and 18 GHz. It may be seen that at the array resonance the FSH response is close to that of the copper horn, whereas away from this frequency it approaches the open waveguide.

Further work on the horn antenna will include investigation into the relationship between the element and lattice design and FSH performance, e.g. crosspolar field levels, gain and frequency response. There are many possibilities here yet to be investigated and exploited; for example the FSH may offer significant pre-receiver selectivity in frequency and polarisation. It may also be possible to measure the RCS of the FSH and compare this with a measurement of a similar copper horn to assess the possibilities for dynamic RCS control using active arrays. It is possible that, for fixed frequency applications, the FSH may already offer significant advantages in terms of weight and out-of-band RCS, both of which should be much lower than for comparable traditional horns. In order to exploit these advantages it will be necessary to develop the measurement prototype into a more robust form and to investigate fully the mode content of the fields in and around the aperture of the FSHs, adopting modal techniques used to analyse multilayer surfaces.

It is envisaged that new lattice geometries will be required to account for the distortion encountered during the folding of the sheet into a cone shape, and possibly for the different incident field conditions found at different positions on the cone. Suitable arrangements of array elements may allow the boundary conditions on the FSH walls to approximate those found on the inside of corrugated horns. This would yield horns with performance similar to corrugated designs that are also lightweight.

Reference

[1] Vardaxoglou, J.C., Seager, R.D. and Robinson, A.J. : 'Waveguide and aperture antenna including frequency selective surfaces', International Patent, 1992, Filing No. PCT/GB92/01173.

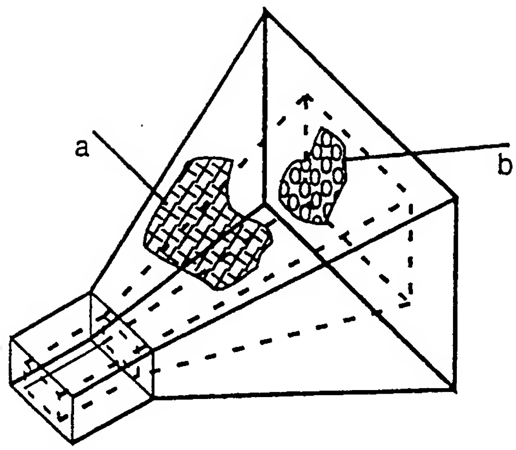

Figure 1. Example of a multiband pyramidal horn using passive array walls.
(a) Low frequency horn showing section of the array. (b) Higher frequency horn.

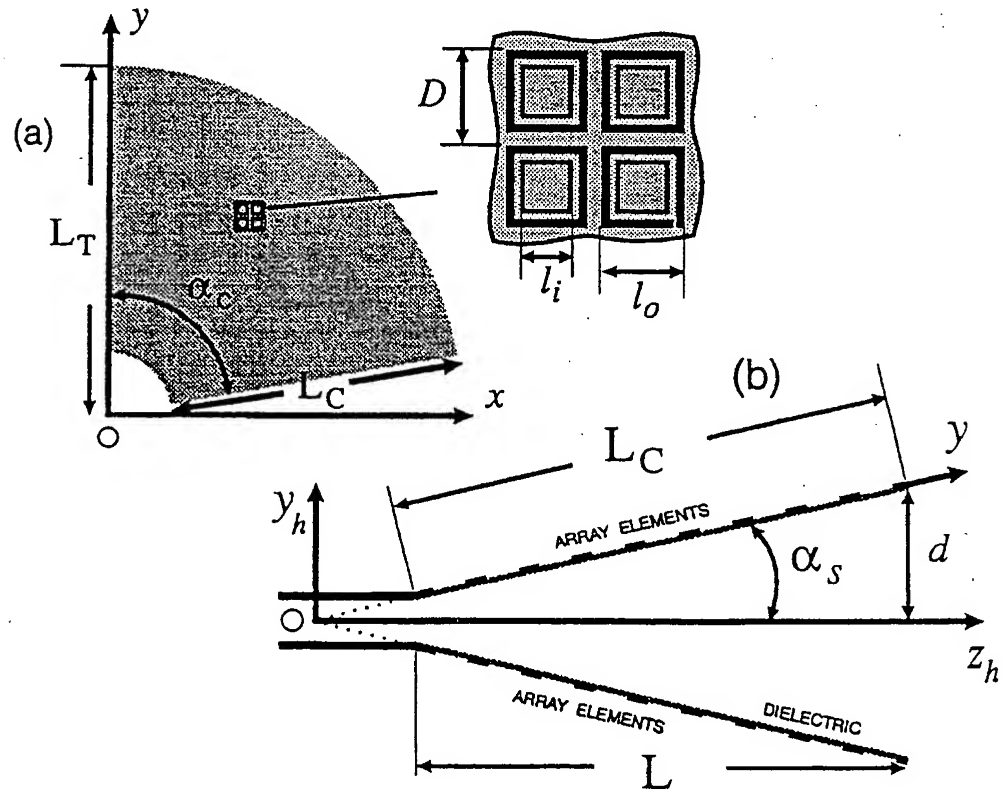

Figure 2. (a) Top view of planar sector showing the geometry and orientation of double-square array (b) Cross section of conical frequency selective ('soft') horn.

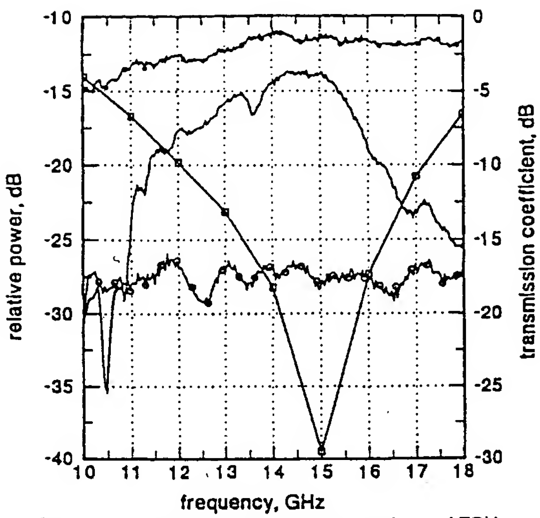

Figure 3. Frequency response comparison of FSH, solid horn and open ended waveguide.

—— FSH ('soft horn')

—●— solid horn

—○— open ended waveguide

—□— flat array plane wave transmission (right y axis)

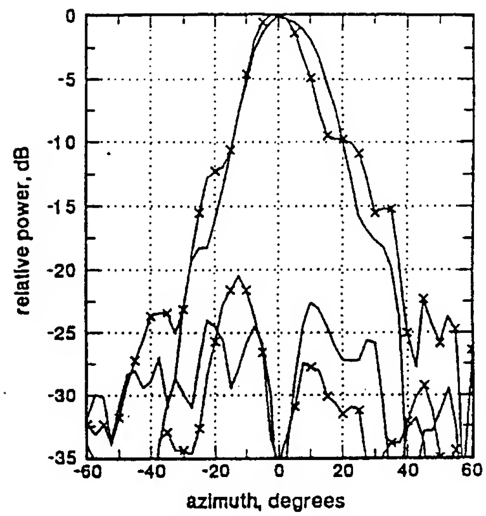

Figure 4. Copolar and crosspolar patterns of 'soft' horn at 14.5 GHz —— H plane

—×— E plane

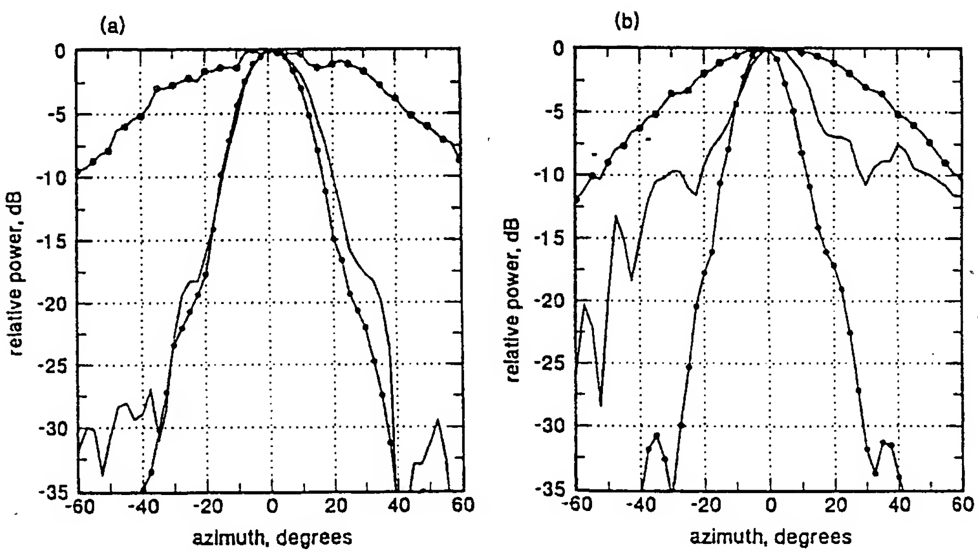

Figure 5. Comparison of H-plane radiation patterns.

(a) 14.5 GHz, (b) 18 GHz. Symbols as in Fig.3.